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Utilization of Plant Capacity in MINNESOTA Dairy Manufacturing Firms

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SUMMARY

Minnesota dairy manufacturing plants generally did not utilize plant capacity fully during 1963. A study of 83 sample plants in six size groupings showed that only special products plants used more than 100 percent of capacity on the peak day. This occurred by stretching the operating time before cleanup or increasing machine use beyond rated levels. All other plant groups reported from 68 to 90 percent of their plant capacity was used on the day of peak milk receipts. On the day of lowest receipts, utilization in all plants ranged from 27 to 42 percent.

Of the major items of equipment in the sample plants--butter churns, spray driers, and cheese vats--capacity of the spray drier was the most fully utilized. On the average, all plants utilized 98 percent of capacity daily.

Peak-day receipts most often occurred in May and low-day receipts occurred primarily in September. In general, larger plants had longer flush periods and shorter slack periods than smaller plants. All plants but one operated 7 days a week during the flush period; 85 percent of the plants processed milk 7 days a week during the slack period.

The major plant receipts during 1963 were whole milk and skim milk. Total receipts ranged from about 14 million pounds to nearly 197 million pounds during the year. Cream, most of which was presumably in the form of farm-separated cream, was received mainly in small plants and comprised a very small part of daily receipts.

The factors most highly correlated with plant capacity were daily milk receipts, cheese vat capacity, and holding capacity.

UTILIZATION OF PLANT CAPACITY IN MINNESOTA DAIRY MANUFACTURING FIRMS

by Orval Kerchner 1/

INTRODUCTION

Productive capacity is one of the oldest and most frequently used concepts in economics. It is also one of the most elusive. A wide range of meanings has been attached to it, depending in part upon the purpose for which the concept is to be used and in part upon whether the problem involved is examined in engineering or economic terms.

The term capacity is usually defined as the quantity of output that a plant can produce per unit of time with a given supply of equipment, labor, and materials. It is usually assumed that labor and materials will be available in the necessary quantities and qualities and that the limiting factors are the size of plant and equipment. Operating standards which determine the intensity of use are also involved in measuring capacity.

For purposes of this study, the capacity of a dairy manufacturing plant refers to the total volume of milk which could be manufactured into dairy products during a 24-hour period, including time for cleaning equipment.

This study deals with capacity as utilized in dairy plants operating in Minnesota during 1963. Plant capacity, receipts, and other plant characteristics, including utilization of capacity, are discussed and various factors associated with capacity utilization are analyzed.

The Sample

Managers of 83 dairy manufacturing plants in Minnesota were interviewed in the summer of 1964. These respondents furnished data for 1963 and in some cases for 1964. Findings in this report provide a benchmark for researchers interested in analyzing changes in utilization of capacity over time.

The sample plants were selected from a list of 388 plants which produced butter, dry milk products, and cheese, either alone or in combination, during 1962. The list of these plants was compiled from dairy plant reports filed with the Minnesota Department of Agriculture.

The 388 plants were ranked by total pounds of raw material received in 1962--whether in the form of whole milk, skim milk, cream, buttermilk, or whey. Seven size groups evolved from this ranking (table 1).

The smallest 75 plants, each of which received less than 4.5 million pounds of raw materials in 1962, were eliminated from further consideration in the study because their receipts were insignificant relative to those of larger plants. Many of these plants are leaving the industry and cannot feasibly be reopened even under

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emergency conditions. During 1963 and 1964, 16 of the 75 plants (21 percent) ceased operations. In many instances, the equipment of the remaining plants was obsolete and in need of repair.

Table 1.--Number of dairy manufacturing plants, total and in sample, by plant group, Minnesota

Plant group	All plants 1/		Plants surveyed 2/		
	Annual receipts per plant	Total plants in group	Number in sample	Number of alternatives	Total
	1,000 lbs.	Number			
Very small	less than 4,500	75	0	0	0
I	4,500- 9,999	72	4	3	7
II	10,000- 17,999	79	7	3	10
III	18,000- 29,999	74	8	3	11
IV	30,000- 99,999	56	34	8	42
V	100,000-340,000	12	12	0	12
Special products 3/	4,500-230,000	20	4/ 18	0	4/ 18
Total	---	388	83	17	100

1/ Plants manufacturing butter, dry milk products, and/or cheese in 1962.
2/ Plant managers interviewed during 1964.
3/ Plants producing dry milk products only, cheese only, and cheese in combination with other products.
4/ All 20 plant managers in the group were interviewed, but 2 did not provide usable data.

Of the remaining 313 plants in the population, the product-mix was as follows:

Product	Number of plants
Cheese	4
Cheese and butter	2
Cheese, butter, and dry milk products	4
Cheese and dry milk products	1
Dry milk products	9
Butter and dry milk products	61
Butter	232
Total	313

The first 5 product types listed in the tabulation were classified as the special products group (table 1). The 20 plants in this group produced cheese exclusively, or in combination with other products, and dry milk products only. This group was selected for total sampling to ensure representation of all types of plants except those producing butter, and butter and dry milk products. Two of the 20 plants did not provide usable data.

Those plants receiving 100 million pounds or more of raw material annually were also selected for total sampling, to include all the largest dairy manufacturing plants in the analysis. This group of 12 plants accounted for approximately 23 percent of the volume received by the total population of 388 plants. These 12

plants (which produced butter only, or butter and dry milk products) are designated as group V in table 1.

With 75 extremely small plants excluded, 20 plants in the special products group, and 12 in group V, there were 281 plants remaining from which a random sample was selected. 2/ The sampling procedure yielded a total of 53 plants distributed among four plant groups. There were 4 plants in group I, 7 in group II, 8 in group III, and 34 in group IV. In addition to the regular sample plants, 17 alternate plants were surveyed (table 1).

A total of 83 plants made up the sample on which the analysis of capacity utilization in this report is based. The locations of the 83 plants illustrate the area in Minnesota where milk production and dairy manufacturing plants are most concentrated (fig. 1). Minnesota's dairy belt, extending from the southeastern corner of the State to the North Dakota boundary near Fargo, is about 70 miles wide.

CHARACTERISTICS OF PLANTS

Age and Ownership

The average age of the plants surveyed was 39 years (table 2). The newest plants, those in the special products group, had an average age of 29 years. The smaller size groups, I-III, contained the oldest plants.

Table 2.--Average age and type of ownership of 83 Minnesota dairy manufacturing plants, by plant group, 1964

Plant group	Average age	Type of ownership			
		Individual	Corporate	Cooperative	Total
	Years	Number			
I	44	--	--	4	4
II	56	--	--	7	7
III	41	--	--	8	8
IV	43	1	2	31	34
V	37	--	1	11	12
Special products	29	2	7	9	18
All plants	39	3	10	70	83

Cheese plants, which made up the greater part of the special products group, were new compared with butter plants. The change from a cream plant to a butter plant was easier than from a cream plant to a cheese plant because of technology, raw material receipts, and markets. A creamery which primarily received farm-separated cream could be converted to a butter plant by adding a churn and storage facilities, whereas a cheese operation required whole milk. Early creameries received cream from farmers and also whole milk from which the cream was retained at the plant and the skim milk returned to the farmer for feed. The greater availability of market outlets for butter than for cheese also facilitated the shift from cream to butter.

2/ See Appendix for details of sampling procedure.

LOCATION OF 83 MINNESOTA DAIRY MANUFACTURING PLANTS SURVEYED IN 1964

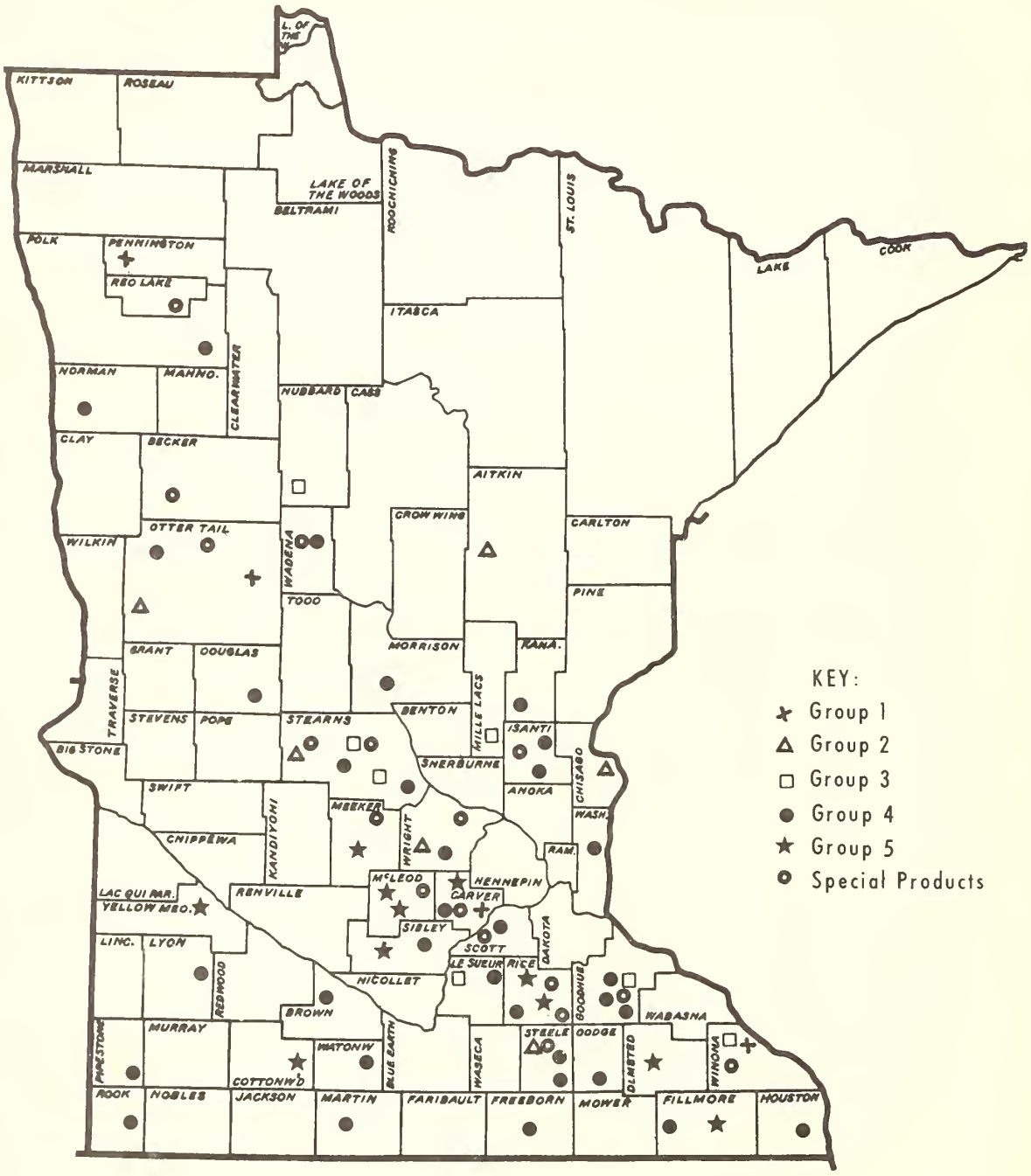

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Figure 1

Nearly 85 percent of the sample plants were owned and operated by cooperatives. Only 3 plants were owned by private individuals and 10 were organized as corporations. None of the group I, II, and III plants were privately or corporately owned. This tends to indicate the historical importance of the cooperative movement in the organization of the Minnesota dairy industry.

Manufacturing Possibilities

Plant managers listed the products currently being manufactured and those which could be manufactured with the present equipment and labor force. Products currently manufactured were largely butter and nonfat dry milk. In 1964, about 80 percent of the 83 plants reported the manufacture of butter; 47 percent manufactured nonfat dry milk; and nearly 28 percent produced dry buttermilk (table 3).

The group V plants produced more dairy products than any other plant group--3.17 products per plant. The smaller plants (groups I, II, and III) produced only 1 product, butter, per plant. Group IV plants averaged 2 products per plant, usually butter and nonfat dry milk with some dry buttermilk, ice cream, evaporated milk, dry whole milk, and powdered ice cream mix. The special products plants produced an average of 2.06 products per plant, with American cheddar cheese, butter, and dry products the major outputs.

Additional products which could be manufactured were generally of the condensed or dry variety, products requiring use of the evaporator and drier equipment. None of the smaller plants could manufacture additional products. The plants in group IV reported that they could manufacture an average of 2.2 additional products per plant, group V plants stated a potential for 2.8 additional products, and special products plants reported 1.2 additional products.

Table 3.--Number of dairy manufacturing plants producing specified products, 83 Minnesota plants, by plant group, 1964

Product	Plant group							
	I	II	III	IV	V	Special products	Total	Percentage of 83 plants
	Number of plants							Percent
Butter	4	7	8	31	12	5	67	80.7
American cheddar cheese	---	---	---	---	---	8	8	9.6
Other cheese	---	---	---	---	---	3	3	3.6
Nonfat dry milk	---	---	---	22	12	5	39	47.0
Dry whole milk	---	---	---	1	---	---	1	1.2
Dry buttermilk	---	---	---	12	6	5	23	27.7
Dry whey	---	---	---	---	---	4	4	4.8
Powdered ice cream mix	---	---	---	1	1	---	2	2.4
Ice cream	---	---	---	1	1	1	3	3.6
Ice cream mix	---	---	---	---	3	1	4	4.8
Evaporated and condensed products	---	---	---	1	2	5	8	9.6
Total	4	7	8	69	37	37	162	---
Plants in group	4	7	8	34	12	18	83	---
Average number of products per plant	Number of products							
	1.00	1.00	1.00	2.00	3.17	2.06	1.95	---

Peaks and Lows

Fluctuations in farm production cause plant receipts to be very seasonal. Respondents indicated that daily receipts during the first 6 months of 1963 were greater than in the last half of the year. The months in which the largest and smallest daily volumes of milk were received are shown in table 4. Of the 83 plants in the sample, 40 percent reported that their peak-day receipts in 1963 occurred in May, and another 28 percent reported March as their peak month (table 4). Sixty percent of the plants stated that their lowest daily receipts occurred in September.

These data are supported by U.S. Department of Agriculture statistics on Minnesota milk production. For the 9 years previous to 1963, May was the month of peak milk production in Minnesota followed closely by March. Monthly milk production figures for Minnesota for the same period indicate September as the low month of the year.

Table 4.--Plants reporting largest and smallest daily milk receipts in specified months, 83 Minnesota dairy manufacturing plants, by plant group, 1963

Plant group	Months with largest daily receipts						Months with smallest daily receipts					
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Number of plants											
I	1	--	--	--	1	2	--	1	2	1	--	--
II	--	--	4	--	2	1	--	3	3	--	1	--
III	--	1	1	--	4	2	--	1	3	2	2	--
IV	1	4	7	3	13	6	2	5	22	4	1	--
V	1	--	4	--	6	1	--	2	7	3	--	--
Special products	1	--	7	--	7	3	--	1	13	2	2	--
Total	4	5	23	3	33	15	2	13	50	12	6	0

The length of the flush and slack periods varied among plant groups. Generally, the larger plants experienced longer flush periods and shorter slack periods than smaller plants (table 5). This may be attributed to the fact that larger plants make a greater effort to persuade milk producers to even out production. In addition, the larger plants tend to receive their milk supplies from large producers who attempt to manage their herds for more uniform production throughout the year. Another contributing factor may be that large plants make a concerted effort to purchase milk from small plants during slack periods.

The flush period ranged from almost 3 months for group I plants to over 5 months for group V plants. Variation in length of the slack period was less pronounced, ranging from 1 1/2 months to just under 3 months. The average for all plants was about 4 months in the flush period and a little more than 2 months in the slack period.

Operating Schedule

The hours that plants operated varied considerably depending on size of plant and kind of products produced. On the peak day in 1963, the smaller plants, groups I, II, and III, operated 10 hours or less while the larger plants and the special products plants operated about 20 hours per day (table 6). These times included the necessary time for cleaning the equipment before beginning the next day's run.

Table 5.--Average number of days plants were in flush and slack periods of milk receipts, Minnesota dairy manufacturing plants, by plant group, 1963

Plant group	Period of milk receipts	
	Flush	Slack
	Number of days	
I	82	49
II	124	88
III	94	68
IV	96	64
V	160	67
Special products	137	62
All plants	116	66

Table 6.--Hours plants operated on each peak and low day of milk receipts, Minnesota dairy manufacturing plants, by plant group, 1963 1/

Plant group	Peak day	Low day
	Hours	
I	10.5	8.8
II	9.1	7.0
III	9.9	7.4
IV	18.8	13.5
V	23.7	16.4
Special products	19.9	9.9
All plants	17.7	11.8

1/ All times include setup and cleanup time for equipment in addition to processing time.

Low-day operations ranged from 7 hours to 16 hours per day. The small plants and the special products plants operated less than 10 hours per day during the slack period. On the other hand, the group IV and V plants operated 13 and 16 hours, respectively.

Managers of small plants indicated that one shift of labor was hired the year round. The longer working hours in the flush period were offset by the shorter days during the slack period. Managers of special products plants generally scheduled two shifts in the flush period with staggered hours for part of the crew, and one shift with staggered hours in the slack period.

Group IV plant managers operated a work schedule similar to that of special products plant managers. In a few instances, these plants operated on two non-staggered shifts the year round and paid for overtime during the flush.

The group V plants operated with three shifts in the flush and two in the slack season. The two-shift arrangement enabled managers to schedule vacation time as well as regular maintenance, such as painting, without having to dismiss any plant personnel during the slack period.

Cleanup time was generally the same each day during the year. The equipment, whether used 1 hour or 20 hours a day in processing, required approximately the same amount of cleaning time. The managers of small butter plants allotted 2 hours per day for cleanup. Plants with driers and cheese processing equipment required about 4 hours per day for cleaning. During the flush period, some managers cut this to 3 hours by placing additional men on the cleaning force.

All plants but one operated 7 days a week during the flush period. This one plant had a policy of processing only 6 days per week. During the slack period, 85 percent of the plants processed milk 7 days per week but no plant operated less than 4 days per week. The plants operating less than 7 days per week in the slack period were in the group IV, group V, and special products plants. They had storage facilities for holding milk, whereas the smaller plants did not and were forced to operate each day.

Plant Receipts

The sample plants received several raw materials from farmers or other plants on a regular basis; these products included cream, whole milk, skim milk, buttermilk, and whey.

The cream receipts consisted primarily of farm-separated cream. In 1963, smaller plants received a larger proportion of their butterfat in the form of cream than the larger plants (table 7). The volume of butterfat received in farm-separated cream by 46 plants amounted to 4.2 percent of the butterfat manufactured into butter in 1963.

Table 7.--Butterfat received in cream and utilized in butter production, Minnesota dairy manufacturing plants, by plant group, 1963 1/

Plant group	Plants reporting	Butterfat per plant		Butterfat in cream as percentage of butterfat in butter
		Received in farm separated cream	Manufactured into butter	
	Number	Pounds	Pounds	Percent
I	3	50,394	218,937	23.0
II	5	62,161	413,911	15.0
III	7	95,577	893,558	10.7
IV	23	69,686	1,326,236	5.3
V	4	14,238	4,399,077	3.2
Special products	4	19,354	212,062	9.1
Total	46	311,410	7,463,781	4.2

1/ Includes only plants receiving some farm-separated cream.

Whole milk constituted the major receipts in Minnesota dairy plants during 1963 (table 8). Of the 83 plants in the sample, 77 reported receipts of whole milk and 37 reported skim milk receipts. All plant groups received whole milk. The three smallest plant groups received no skim milk, buttermilk, or whey. Total receipts per plant ranged from almost 14 million pounds to about 197 million pounds; the average for all plants was 86 million pounds.

Table 8.--Average annual receipts of whole milk, skim milk, and buttermilk (or whey), Minnesota dairy manufacturing plants, by plant group, 1963

Plant group	Whole milk		Skim milk		Buttermilk and/or whey		All receipts	
	Plants reporting	Volume	Plants reporting	Volume	Plants reporting	Volume	Plants reporting	Volume
	Number	1,000 pounds	Number	1,000 pounds	Number	1,000 pounds	Number	1,000 pounds
I	4	19,522	--	--	--	--	4	19,522
II	7	13,651	--	--	--	--	7	13,651
III	8	19,200	--	--	--	--	8	19,200
IV	34	44,588	16	23,456	7	44,384	34	64,074
V	12	51,903	10	121,451	6	55,477	18	127,943
Special products	12	146,614	11	15,388	5	7,394	12	196,800
All plants	77	54,876	37	54,433	18	37,806	83	86,390

In 1963, variation between largest and smallest daily receipts of whole milk was quite large, with smallest daily receipts averaging less than 50 percent of largest daily receipts (table 9). By plant groups, smallest daily receipts, as a percentage of largest daily receipts, ranged from 40 percent of the largest in group I to 48 percent in group II plants.

Skim milk receipts varied more than whole milk receipts between the peak and low days. The special products group, composed primarily of cheese making operations, had the largest variation, with the low-day receipts only 20 percent of the peak-day receipts. The average for all plants was about 24 percent.

Buttermilk and/or whey, like skim milk, was received only in the plants with drying facilities. The special products group, which included the specialized drying plants, received considerably more of these raw materials than the group IV and V plants. The low-day receipts averaged about 33 percent of the peak-day receipts for all plants reporting.

Table 9.--Comparison of average peak-and low-day receipts, Minnesota dairy manufacturing plants, by plant group, 1963

Plant group	Whole milk receipts				Skim milk receipts				Buttermilk and/or whey			
	Plants reporting	Volume per plant			Plants reporting	Volume per plant			Plants reporting	Volume per plant		
		Peak day	Low day	Low/ peak		Peak day	Low day	Low/ peak		Peak day	Low day	Low/ peak
	Number	1,000 lb.		Pct.	Number	1,000 lb.		Pct.	Number	1,000 lb.		Pct.
I	4	66.5	26.5	39.8	---	---	---	---	---	---	---	---
II	7	61.9	29.9	48.3	---	---	---	---	---	---	---	---
III	8	90.8	37.2	41.0	---	---	---	---	---	---	---	---
IV	32	202.5	89.0	43.9	16	219.5	72.2	32.9	3	52.0	7.0	13.5
V	12	581.1	274.1	47.2	10	323.3	143.7	44.4	1	61.0	33.0	54.1
Special products	10	260.7	114.1	43.8	7	517.1	103.0	19.9	4	395.8	136.0	34.4
All plants	73	239.5	108.1	45.1	33	413.6	100.4	24.3	8	225.0	74.8	33.2

Average total receipts, including whole milk, cream, skim milk, buttermilk and whey, ranged from 62,000 pounds to 856,000 pounds per plant per day in 1963. Average volume of raw materials received by all plants for processing on the peak day was 357,000 pounds (table 10).

Low-day receipts ranged from 26,000 pounds to 397,000 pounds per plant, and the average for all plants was 142,000 pounds. For all 83 plants in the sample, low-day receipts averaged 40 percent of peak-day receipts.

Plant Capacity

As stated earlier, the capacity of a plant refers to the total quantity of raw materials which can be processed in the plant during 1 day of 24 hours including cleaning time. The raw materials considered in determining capacity included whole milk, skim milk, buttermilk, and whey. The extent of a plant's capacity was determined by the physical limitations of the equipment used in processing milk into various products. (Capacity in terms of individual pieces of equipment is discussed later.)

Plant capacity ranged from 85,000 to 953,000 pounds of raw materials per plant per day (table 10). The average capacity for all plants was 391,000 pounds per day.

The large plants utilized a greater proportion of plant capacity on peak days than the small plants. On the other hand, low-day capacity utilization varied little between the small and large plants. For all plants, utilization of capacity averaged 91 percent on the peak day and 36 percent on the low day.

Only the special products plants utilized more than 100 percent of capacity on the peak day. A capacity utilization greater than 100 percent may reasonably occur for short periods of time by shortening the cleanup time, accelerating the drier capacity by using higher-than-usual temperatures, or shortening the washing time for butter before it leaves the churn. Of the many practices which may be used to step up plant output during the flush season, running equipment longer periods between cleanups seems most prevalent. Instead of operating 20 hours and shutting down 4 hours for cleaning, a plant may run 30 to 36 hours before cleanup is performed.

Table 10.--Comparison of capacity and receipts, peak and low days, 83 Minnesota dairy manufacturing plants, by plant group, 1963

Plant group	Number of plants	Average daily capacity	Average receipts: Peak day	Average receipts: Low day	Capacity utilized: Peak day	Capacity utilized: Low day
		1,000 pounds			Percent	
I	4	98	67	26	68	27
II	7	85	62	30	73	35
III	8	119	91	37	76	31
IV	34	339	298	118	88	35
V	12	953	856	397	90	42
Special products	18	418	434	134	104	32
All plants	83	391	357	142	91	36

Holding Capacity

Stainless steel tanks into which milk was pumped from farm trucks, cream storage tanks, and other permanent storage tanks were considered in determining holding capacity. This holding capacity was assumed to be the total available at one point in time for whole milk, skim milk, cream, buttermilk, and whey.

The average capacity to hold raw materials in 1963 was about the same in the three smallest plant groups, ranging from 61,000 to 73,000 pounds (table 11). Group IV and special products plants had average holding capacity of 248,000 and 222,000 pounds, respectively. The group V plants maintained the largest holding capacity, with an average of 634,000 pounds per plant.

Comparing the receipts to holding capacity indicates that, on the average, plants have facilities to hold 72 percent of their peak-day receipts of raw materials (table 11). Special products plants received enough whole milk and other raw materials to fill the storage tanks 1.95 times on the peak day. Group I plants did not fill the tanks on the peak day, as shown by the ratio of 0.92.

While some plants run their operations on milk received for a relatively short period of time during the day, other plants receive milk throughout the operating day, thus utilizing the holding capacity to a greater extent. The small plants operate 8 to 12 hours and the large plants 20 to 24 hours during the peak season.

If supplies do not arrive at the plant at a uniform rate throughout the day, substantial holding capacity enables plants to maintain sufficient supplies of raw material to operate the whole day. An alternative when receipts are "uneven" would be to operate processing equipment with larger capacity, but this equipment is more costly and less flexible than storage tanks.

Table 11.--Milk holding capacity and peak-day receipts, Minnesota dairy manufacturing plants, by plant group, 1963

Plant group	Number of plants	Average holding capacity 1/	Average peak-day receipts 2/	Ratio of receipts to holding capacity	Capacity as percent of receipts
	No.	1,000 lb.	1,000 lb.	Ratio	Percent
I	4	73	67	0.92	109
II	7	61	62	1.02	98
III	8	71	91	1.28	78
IV	34	248	298	1.20	83
V	12	634	856	1.35	74
Special products	18	222	434	1.95	51
All plants	83	257	357	1.39	72

1/ Storage facilities available for holding whole milk, skim milk, cream, buttermilk, and whey at one point in time.

2/ Includes whole milk, skim milk, cream, buttermilk and/or whey received at plants on the peak-volume day.

Capacity of Processing Equipment

In addition to the capacity to hold raw materials, the capacity of the equipment to process the milk is an important aspect of plant operations. The size of the equipment varies from plant to plant and affects milk processing time, as well as labor, fuel, and other input requirements.

The major items of equipment in the sample plants considered in determining the plant's processing capacity were butter churns, spray driers, and cheese vats. Other items of equipment which prevented increasing the volume of milk processed are discussed in the next section.

Plant managers furnished data on the equipment capacity according to the output of each machine (table 12). Butter churn capacity is generally referred to as pounds of butter per churning, and cheese vats are said to yield specified pounds of cheese per batch. However, spray drier capacities are expressed in terms of powder produced per hour of operation.

Except in special products plants, capacity of the butter churn increased as plant size increased. Group I plants had an average churn capacity of 1,650 pounds of butter per churning and group V plants had capacity for 5,514 pounds. The special products plants group had capacity to produce an average of 3,080 pounds of butter per churning.

Spray driers were used by only the three larger plant groups. Capacity of this equipment in nonfat dry milk production ranged from 1,629 pounds per hour in group IV to 3,290 pounds per hour in group V plants.

The special products plants, the only group reporting cheese production, had vat capacity to produce 9,420 pounds of cheese per batch.

The number of churnings or batches per day depends on the equipment used, the method of cleaning, and other factors affecting butter and cheese production. Equipment technologies and new practices have affected the time requirements in cheese operations. For example, vat time requirements are considerably less when cooking vats and matting tables are used in a plant than when cooking vats are also used for the matting process. Extensive use of stainless steel piping

Table 12.--Average capacity of processing equipment, Minnesota dairy manufacturing plants, by plant group, 1963

Plant group	Butter churn		Spray drier		Cheese vats	
	Plants reporting	Butter per churning	Plants reporting	Nonfat dry milk per hour	Plants reporting	Cheese per batch
	Number	Pounds	Number	Pounds	Number	Pounds
I	4	1,650	1/	---	1/	---
II	7	1,972	1/	---	1/	---
III	8	2,938	1/	---	1/	---
IV	32	3,666	21	1,629	1/	---
V	12	5,514	12	3,290	1/	---
Special products	5	3,080	9	2,967	10	9,420

1/ The particular piece of equipment was not used in these plants.

requires much time for dismantling, washing, and assembling each day. Clean-in-place equipment generally cuts cleaning time and thus increases the number of hours equipment is available for processing.

Factors that affect churning time are the firmness of the butterfat, temperature of the cream, percentage of butterfat in the cream, and amount of cream in the churn. A soft butterfat requires a longer time to churn than a firm butterfat. A higher fat content in the cream will cause "breaking" or butter formation rather quickly, but the fat loss during the milk separation may be greater than if a cream lower in fats were used.

Cheese vat capacities cannot be discussed on an hourly basis because many types of cheese may be produced in the cheese vats in the sample plants. Moreover, cooking times, matting times, and fat content of the milk differ for the various cheeses produced.

Drier capacity was compared with nonfat dry milk and dry buttermilk production for both peak and low days to determine the extent to which the drying facilities were used (table 13). Daily drier capacity was computed from the hourly capacity, assuming that the drier could operate 20 hours continuously before the 4-hour cleaning period began.

On a 20-hour-per-day operation, driers were used at 80 percent or more of their capacity. The very large butter-powder plants utilized 107 percent of drier capacity. Plants can increase their capacity on peak days by running the drier more than 20 hours between cleanings or by increasing the pressure on the evaporated skim milk entering the drying chambers. Both of these methods of increasing output tend to decrease recovery efficiency, but this is considered a minor factor when milk storage is needed for the next day's receipts. Group IV plants utilized 94 percent of drier capacity on the peak day while special products plants used 81 percent of capacity.

In all cases, the low-day utilization of the drier was less than one-half the peak-day utilization. This again is indicative of the seasonality of milk receipts.

As the manufactured dairy products industry adopts new technologies, hourly capacities are likely to become more applicable. One such technology is the continuous butter churn, a machine that takes in cream at one end and yields butter at the other end in a continuous flow.

Table 13.--Drier capacity and powder production on peak and low days, Minnesota dairy manufacturing plants, by plant group, 1963

Plant group	Plants reporting	Average daily drier capacity 1/	Average daily powder production 2/		Daily utilization of drier capacity	
			Peak	Low	Peak	Low
	Number	1,000 lb.	1,000 lb.	1,000 lb.	Pct.	Pct.
IV	21	32	30	12	94	38
V	11	68	73	33	107	49
Special products	3	73	59	23	81	32
Total	35	47	46	20	98	43

1/ Capacity computed from hourly rate, assuming 20 hours of operation and 4 hours for cleanup.

2/ Includes nonfat dry milk and dry buttermilk.

Bottlenecks

Plant managers were asked, "What do you consider to be the bottlenecks (physical limits of equipment) in the plant which prevent you from increasing the amount of raw material processed in your plant?" The answers, tabulated in table 14, take into account the operating schedule and available labor at the time of the interview.

The drier was most often mentioned as being a limitation to increasing plant capacity, with the given labor and operating schedule. Holding capacity, separator, cheese vats, and refrigeration 3/ were also termed bottlenecks.

Table 14.--Number of plants reporting specified bottlenecks to increasing plant capacity, Minnesota dairy manufacturing plants, by plant group, 1964

Plant group	Holding capacity	Separator	Drier	Cheese vats	Refrigeration
	Number				
I		1			
II	1	1			1
III		1			1
IV	2	1	11		3
V	1		1		
Special products	1		2	1	
Total	5	4	14	1	5

PLANT ALTERNATIVES

Most of the plants in the sample were considered to be specialized plants because they manufactured only one product or joint products such as butter and nonfat dry milk. Plants that manufactured other dried milk products along with nonfat dry milk and those that made butter, nonfat dry milk, and cheese diversified because their products competed for whole milk receipts.

Managers were asked to cite the advantages and disadvantages of specialization and diversification. Managers of 15 plants expressed the view that there was considerable difficulty in changing a specialized plant into a diversified plant (table 15). Much of the difficulty may be linked to opinions given by other plant managers; for example, some stated that it stemmed from reluctance on the part of cooperative membership or the board of directors to change a well-established organization.

Other managers believed that the investment in equipment needed to diversify the specialized plant was too great. Conversely, some managers felt the expense was warranted because it enabled them to take advantage of price changes in the market. Managers linking inefficiency with diversification were of the opinion that other costs in addition to equipment would not permit returns great enough to diversify. Opinions such as "additional types of labor skills," "chance of losing market outlets," and "lack of necessary volume" also indicated that diversification was inefficient.

3/ Refrigeration refers to the equipment which provides cold water for cooling milk and cream and is commonly called the "sweet water" system.

Table 15.--Number of managers reporting specified opinions on diversification as opposed to specialization, Minnesota dairy manufacturing plants, by plant group, 1964

Plant group	Too much trouble to change	Equipment too expensive	Requires large milk supply	Permits exploitation of price change	Inefficient	Miscellaneous 1/
	Number					
I	--	1	3	--	--	--
II	3	--	1	--	1	--
III	2	1	1	--	--	3
IV	5	5	5	5	--	3
V	2	4	--	1	1	--
Special products	3	2	2	1	4	--
Total	15	13	12	7	6	6

1/ Includes opinions: "sign of progressiveness," "too much competition from nearby plants," "labor skills not available."

It was pointed out, particularly by managers of small plants, that the volume of milk was not great enough to diversify the product line. As noted earlier, the small plants did not use their facilities to capacity even in the peak season. Thus, plants in this situation would face serious problems in attempting to diversify.

In general, managers of the sample plants seemed to favor specialization over diversification. Managers of larger plants with larger volumes of milk and some diversity in their operations looked with more favor on diversification. It was apparent that the small, one-product plants had to obtain a greater volume of milk before diversified operations could be considered.

FACTORS ASSOCIATED WITH PLANT CAPACITY

During the interviews, each manager indicated not only the plant's total capacity in terms of daily input but also the capacities of various machines used in the plant. These data, plus other factors, were used in investigating factors associated with plant capacity.

Plant capacity was selected as the independent variable and 12 factors associated with plant operation were designated as dependent variables (table 16). Correlation analysis was used to determine the relationship between plant capacity and each dependent variable. The number of plants in each comparison varied according to the availability of usable data and the relevance of the comparison. For example, cheese vat capacity was not available in all plants and some plant managers failed to report the receipts for the low day.

Nine of the 12 dependent variables correlated with plant capacity yielded significant coefficients of correlation when tested by the "t" test at the 95-percent level. This means that as plant capacity changed, the associated change in each of these dependent variables was significantly different from zero.

Low-day and peak-day receipts showed a strong correlation (r values greater than .95) with plant capacity and the coefficients were highly significant. Holding capacity and cheese vat capacity yielded correlation coefficients greater than .80. While both coefficients were found to be significant, holding capacity was more significant than vat capacity.

Table 16.--Relationship between plant capacity and various dependent variables, Minnesota dairy manufacturing plants, 1963 1/

Dependent variable	Unit	N 2/	a 3/	b 3/	Sy.x 4/	r 5/	Value of t 6/
Products plants could manufacture	Number	17	4.05	7/	1.7	0.029	0.112
Days operated at low	Day	78	71.18	.003	29.2	.046	.402
Days operated at peak	Day	80	114.33	.015	75.3	.080	.705
Drier capacity per hour	100 lb. nonfat dry milk	42	5.06	.032	7.8	.088	11.411
Churn capacity per churning	100 lb. butter	68	26.43	.025	16.1	.167	5.073
Products manufactured	Number	81	1.39	.001	.7	.492	5.018
Hours operated in peak	Hour	82	14.14	.009	5.7	.544	5.812
Annual receipts	Million lb.	83	12.79	.187	72.7	.720	9.351
Holding capacity	1,000 lb.	83	43.78	.546	150.1	.823	13.020
Vat capacity per batch	1,000 lb. cheese	10	28.14	.218	39.8	.846	4.494
Low-day receipts	1,000 lb.	77	-4.54	.383	47.5	.957	28.664
Peak-day receipts	1,000 lb.	80	-14.33	.915	75.2	.980	43.441

1/ Plant capacity--the independent variable in the estimating equation--is expressed in thousands of pounds of raw material receipts per 24-hour day.
2/ Number of observations.
3/ Values in estimating equation of the form $Y = a+bX$.
4/ Standard error of estimate.
5/ Coefficient of correlation.
6/ Values shown are those computed in testing significance of the b and the r coefficients and may be compared with a table of the "t" distribution.
7/ Less than .001.

Of the three major pieces of equipment, the capacity of the cheese vats had a greater degree of association with plant capacity ($r = .85$) than the butter churn ($r = .17$) or drier ($r = .19$) capacities.

The number of products which a plant could manufacture, the days operated during the slack season, and the days operated during the flush season yielded very low r values when correlated with plant capacity. Each of these three values was found to be insignificant when tested at the 95-percent level of confidence.

CONCLUSIONS

It is generally concluded that the capacity of Minnesota dairy manufacturing plants is not fully utilized even in the flush period. This unused capacity is a two-edged sword. On the one hand, it is costly to maintain and operate extra plant and equipment which are only partially utilized. On the other hand, these extra facilities provide additional capacity in emergency situations when more capacity is needed immediately.

Most plant receipts were in the form of whole milk and skim milk. Very little farm-separated cream was received and the small plants received most of it. The steadily declining amount of farm-separated cream available probably has contributed to the demise of small dairy manufacturing plants in Minnesota. In order to survive as butter plants, the small plants must compete with larger plants for whole milk supplies. They have expanded plant facilities only to find it difficult to obtain sufficient milk to operate at full capacity. The result is unused capacity.

Analysis of various factors as related to plant capacity clearly indicates that plant receipts and plant capacity are highly correlated. Milk production and therefore plant receipts are seasonal. To meet the seasonal peaks, plants were built to handle the milk supplies during the flush period. Unused plant capacity during the slack period is the result for many dairy manufacturing plants in Minnesota.

Leveling out milk supplies delivered to plants during the year would reduce the amount of unused capacity. One obvious solution to the problem of underutilized capacity is to level out milk production patterns through milk cow breeding and feeding programs. Alternatively, managers of multiplant operations could consider closing one plant during slack periods and transfer milk to other plants. Managers of single-plant operations could arrange to sell milk to another plant and cease local operations. Employees could take vacations and perform repair and mainteance duties during this time when the plant is not engaged in producing dairy products.

APPENDIX

PROCEDURE FOR SAMPLE SELECTION

The problem involved drawing a sample of plants from a known population, consisting of dairy manufacturing plants which made either butter, dry milk products, and/or Cheddar cheese. The criterion for drawing a sample was based on total raw material receipts for the year 1962 as taken from the annual dairy plant reports submitted to the Minnesota Department of Agriculture.

The size of sample needed from the four groups totaling 281 plants was determined by the following formula: 4/

$$n = \frac{k^2 N V^2}{ND^2 + k^2 V^2}$$

where n = sample size,

k = probability (confidence limits),
N = population size,
V = coefficient of variation (V^2 = rel-variance), and
D = allowable relative difference between the estimated mean and the true mean.

This formula determined the size of sample necessary to obtain results of specified precision. Interest centered around having a satisfactory degree of certainty that the sample estimate of a particular characteristic was in error by no more than a specified amount, or that the error made was not more than a specified proportion of the value being estimated.

The value of V was determined from the formula:

$$V = \frac{\sigma}{\bar{X}}$$

where $\sigma = \sqrt{\frac{\Sigma X^2}{N-1} - \frac{(\Sigma X)^2}{N(N-1)}}$ = the standard error of the mean of the population values of the raw material receipts, and

$$\bar{X} = \frac{\Sigma X}{N} = \text{mean},$$

where ΣX = total pounds of raw material received in 1962, and
N = 281 = population size.

The value of k was established at 2. This set the confidence limits at 95 percent. The value of D was established at 0.2.

4/ Hansen, Morris H., William N. Hurwitz, and William G. Madow. Sample Survey Methods and Theory, Volume I, Methods and Applications. New York, John Wiley and Sons, Inc., 1960, p. 127.

The total sample size was determined to be 53. To determine the size of the sample to be taken from each stratum, the following formula was used: 5/

$$n_g = \frac{N_g \ \sigma_g}{\Sigma N_g \ \sigma_g} (n)$$

where n_g = sample size from group,

N_g = population size of group,

σ_g = standard deviation of group, and

n = total sample size.

Once the size of each stratum was known, the plants were selected randomly with the aid of a table of random numbers. 6/ The following tabulation indicates the number selected in each group:

Group	N_g	n_g	Alternates
I	72	4	3
II	79	7	3
III	74	8	3
IV	56	34	8
Total	281	53	17

5/ Hansen, et al, p. 209.

6/ Arkin, Herbert, and Raymond R. Colton. Tables for Statisticians. Barnes and Noble, Inc. New York, 1959, table 23, pp. 142-145.

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